TITLE

Do Resource Constraints Trigger or Hamper Innovation?

A longitudinal study of UK high-tech firms

CO-AUTHORS

Dr Rebecca Liu
Lancaster University Management School
Charles Carter Building
Lancaster LA1 4YX, United Kingdom
+44 (0) 1524 594767
rebecca.liu@lancaster.ac.uk

Dr Josh Siepel
University of Sussex
Science Policy Research Unit (SPRU)
Brighton BN1 9SL, United Kingdom
+44 (0) 1273 876711
j.siepel@sussex.ac.uk

Professor Marc Cowling
University of Brighton
Brighton Business School
Moulsecoomb
Brighton, BN2 4AT
+44 (0)1273 641232
M.Cowling2@brighton.ac.uk

ABSTRACT

This paper explores whether firms resource constraints trigger or hamper innovation using a ten-year longitudinal study. It contributes to the longstanding theoretical debate between the resource-based and entrepreneurship views of the firm. Scholars from the resource-based perspective argue that resource constraints increase delays and unpredictable results, which thereby to impede innovation. Entrepreneurship research however suggests that organizations avoid experimentation if resources are available, and that resource scarcity therefore stimulates managers to adopt entrepreneurial practices that foster innovation. This points to our imperfect understanding on the issue.

This paper contributes to both theoretical advance and managerial practice. First, to correct the bias from a disproportionate amount of interest to financial barriers, we provide a more balanced and integrated view by considering other important resource constraints. Second, to observe the difference of two types of innovation, we augment the literature by studying the effects of resource constraints on both incremental and radical innovativeness and on firms' performance of sales and R&D growth. Finally, the issue of resource constraints is an inevitable challenge, and the findings of the paper provide some guidance to managers and innovators who are struggling with the lack of resources on one hand and with the pressure of innovation and competitiveness on the other hand.

This paper is unique in presenting a long-term, longitudinal analysis of the impact of resource constraints on innovation, both radical and incremental. It presents a ten-year longitudinal study following 362 firms through the life cycle. We use panel analysis techniques to observe the impact of resource constraints on subsequent innovative performance. A research framework is derived from the literature review. We examine the knowledge shortfalls of: management; market; sales; production; R&D and finance. This

analysis is based upon a unique, longitudinal panel dataset of 241 UK and German firms in six technology-based sectors over ten years. The dataset draws upon performance data as well as the results of detailed managerial surveys that were carried out in the UK and Germany. This, combined with information provided by interviewees about the firms' characteristics upon founding, provides a unique and rich longitudinal perspective on factors contributing to the long-run performance of these firms. This study is based on two surveys that were carried out in 1997 and again in 2003. Using these databases, all firms with at least three employees in 1997 that were operating in one or more high-tech sectors and having been founded as legally independent companies between 1987 and 1996 were selected; the mean year of founding was 1991. Our approach to the problem involves initial use of panel logit models to predict the likelihood of a firm engaging in incremental or radical innovation. Our model is specified in a manner that we consider the lagged effect of the resource constraints in t0 on propensity for innovation in period t1. Our other controls listed above all are used for period t1. Given challenges in interpreting logit models we present the results in the form of marginal effects. Following from this analysis we then use panel OLS models to explore the impact of these constraints on subsequent innovation and growth performance.

Does the lack of knowledge hamper or trigger innovation? The answer is rather mixed. While our study indicates that the lack of knowledge may not hamper innovation development for both incremental and radical, it suggests that the lack of knowledge does matter when considering sales growth and R&D growth.

For radical innovation, our study suggests that the lack of management knowledge may trigger sales growth. Un-surprized, the lack of R&D knowledge triggers R&D growth of firms. This may be explained in two ways. First, the lack of R&D knowledge leads firm to increase R&D investment. Furthermore, the nature of radical innovation may also lead the innovative firms to discard prior R&D knowledge in order to build up new R&D knowledge. Finally, our study echoes the extant literature that the lack of financial knowledge hampers the R&D growth.

For incremental innovation, our study once again stresses the significant impact of the lack of financial knowledge on innovation and suggests that the shortfall of financial knowledge hampers sales growth. It further suggests that the lack of market knowledge hampers R&D growth. This result also suggests that market knowledge is critical for firms in deciding their R&D investment. Finally, our study suggests that the lack of production knowledge triggers R&D growth. Managers tend to increase R&D investment when they need production knowledge.

Through a ten-year longitudinal study, our study contributes to the existing literature by advancing the understanding of the association between resources constraints and innovation. Building on the theories of human capital, entrepreneurship and RBV, we shed light about the impact of knowledge shortfalls on both radical and incremental innovation. Finally, our study helps to explain the disputes of whether resource constraints hamper or trigger innovation. The study also has implications for executives and managers. It demonstrates that managers can harness the entrepreneurship practices by minimizing their interference for radical innovativeness. Managers and innovators hare encouraged to update their market knowledge that serves an important indicator for R&D investment. Furthermore, as suggested by many researchers, financial knowledge is always important in operating and managing innovation for both sales and R&D growth. Indeed, innovative firms face problems and more innovative firms have more problems. The issue of resources constrains is not only critical but also difficult to deal with. We hope our paper inspires researchers to conduct further research in the future.

INTRODUCTION

It has been widely recognised that a firm's resources and innovation activity are crucial factors in determining its growth and competitiveness. At the same time, virtually all organisations are resource constrained in some way, and dealing with these challenges is a predominant theme in the literature. In particular, specific attention has been widely paid to the topic of resource constraints and their impact on innovation performance (see Bader and Nelson 2005; Katila and Shane 2005; Gibbert and Scranton 2009). Prior research on the association between resources constraints and innovation performance however has produced mixed, even contradictory, results (Keupp and Gassmann 2014; García-Quevedo et al. 2014; Mohnen and Röller 2005; Tiwari et al. 2007; Savignac 2008; Mancusi and Vezzulli 2010; Hottenrott and Peters 2011). Scholars based within the resource-based view argue that a lack of resource leads to a probability for delays and unpredictability of results, which tend to impede research and development (R&D) and innovative activities (see Camison-Zornoza et al. 2004; Mone et al. 1998). Researchers coming from an entrepreneurship perspective, on the other hand, suggest that organizations tend to avoid experimentation if resources are available (Bradley et al. 2010; Cheng and Kesner 1997). Consequently, the approach suggests, resource scarcity stimulates managers to adopt entrepreneurial practices, explore new opportunities and hence trigger innovation (Keupp and Gassmann 2013; Stevenson & Jarillo 1990). It is this contradiction that motivates this study. Our study aims to explore the impact of resource constraints on the innovation and growth of hi-tech firms.

We argue that this contradiction can be attributed to four major limitations in the existing literature. First, because innovation is a lengthy process, there is a lag between resource constraints and subsequent firm performance. In other words, the impact of resource constraints on innovation performance requires a longitudinal observation for the results to emerge. Unfortunately, the majority of prior research (with few exceptions) did not provide us a longitudinal observation (e.g. Mohnen and Röller 2005; Tiwari et al. 2007; Savignac 2008; Mancusi and Vezzulli 2010; Hottenrott and Peters 2011). The second limitation in the existing literature concerns a disproportionate amount of interest to a particular resource – financial obstacles (see Di Stefano et al. 2012 for a recent review). This bias overlooked other important hindrances that firms face when managing innovation projects. A more balanced view is urgently called by many scholars (e.g. García-Quevedo et al. 2014; D'Este et al. 2012). The third limitation lies in the nature of innovation. Differences exist for the required resources between radical and incremental innovation. The existing literature (with few exceptions) however treats innovation as one single endeavour (e.g D'Este et al. 2012; Iammarino et al. 2009). This limitation may lead to a biased conclusion due to the underlined differences of required resources. The final limitation is that of data: the Community Innovation Surveys run throughout the EU, whilst tremendously valuable, provide the basis for the vast majority of this literature (for instance Mohnen and Röller 2005, Iammarino et al 2009, D'Este et al 2012, Keupp and Gassmann 2014 and many more). While CIS studies have helped us to expand our understanding of the topic considerably, the common questions – which specifically focus on barriers to innovation - mean that the scope of insights potentially generated are limited by those questions asked, and may not directly map as clearly the relationship between resource constraints and innovation outcomes. Other data sources therefore have the potential to generate further insights.

This paper addresses these issues. We focus on the shortfall of skills/knowledge, one of the major resources in developing and managing innovation. We investigate the lack of knowledge, know-how and skills of market, finance, management, production, R&D, and sales. We examine their effect on radical and incremental innovation. Since innovation has been long recognised as a crucial factor in determining the growth and competitiveness of firms, we further examine the impact of the resource constraints on the growth of sales and R&D expenditure. We present a ten-year longitudinal study following 362 high-tech firms through the life cycle. The dataset is unique in that the relevant activities and behaviours of the same sample firms were recorded and observed for over ten years. We use panel analysis techniques to observe the impact of resource constraints on subsequent innovative and growth performance. A research framework is derived from the literature review.

This paper contributes to both theoretical advance and managerial practice. First, to correct the bias from a disproportionate amount of interest to financial barriers, we provide a more balanced and integrated view by considering other important resource constraints. Second, to observe the difference of two types of innovation, we augment the literature by studying the effects of resource constraints on both incremental and radical innovativeness and on firms' performance of sales and R&D growth. Finally, the issue of resource constraints is an inevitable challenge, and the findings of the paper provide some guidance to managers and innovators who are struggling with the lack of resources on one hand and with the pressure of innovation and competitiveness on the other hand.

THEORETICAL BACKGROUND AND HYPOTHESES

Human Capital and Innovation

Since the economist Becker (1964) proposed "human capital theory," research from diverse disciplines, such as economics, strategy, and human resources have converged on the study of how human capital resources are deployed (Ployhart et al. 2014). From an organisational perspective, human capital is defined as 'the knowledge, skills, and abilities residing with and utilized by individuals' (Subramaniam and Youndt, 2005, p. 451). The most distinctive and inimitable resource embedded in human capital is its embodied knowledge, which enables firms to manipulate and transform other organizational resources effectively (Argote and Ingram, 2000; Foss, 2007; Kogut and Zander, 1992). From this view, human capital also provides competitive knowledge-based resources may be particularly important in supporting a sustainable competitive advantage (McEvily and Chakravarthy, 2002). The extant literature has highlighted that human capital is a key driver of the success of firm performance, especially for technology-based firms (Colombo and Grilli, 2010). In line with the prior studies, we focus and summarize our literature review on the lack of knowledge, know-how and skills ('knowledge' hereafter) in management, market, sales, production, R&D and finance. To further investigate the issues, we investigate firms' sustainability by observing their growth in sales turnover and in R&D investment.

The Lack of Management Knowledge/Skills

The management of organizational processes is essential in connecting the firm with internal and external actors in order to facilitate valuable knowledge access for the growth and competitiveness of firms (Keupp and Gassmann 2009). Clausen et al. (2013) have found that the firm's innovative capacity lies in the management of processes that generate new knowledge inside the firm. It is however less clear how much involvement (or any) is adequate in innovation process. The literature has stressed that resource scarcity stimulates managers to adopt entrepreneurial management practices that foster the search for new opportunities (Stevenson and Gumpert, 1985; Stevenson and Jarillo, 1986, 1990). For example, Keupp and Gassmann (2013) suggest that management should harness resource constraints to encourage entrepreneurial action and mangers should adapt their management practices to stimulate such emergence. To advance our understanding, we propose:

H1a: The lack of management knowledge is negatively associated with radical innovation.

H1b: The lack of management knowledge is negatively associated with incremental innovation.

H1c: The lack of management knowledge is negatively associated with sales growth in radical innovation (H1c-a) and in incremental innovation (H1c-b).

H1d: The lack of management knowledge is negatively associated with R&D growth in radical innovation (H1d-a) and in incremental innovation (H1d-b).

The Lack of Market and Sales Knowledge/Skills

Many years ago, Schumpter (1934) has recognised that product innovation is the market introduction and commercialization of new technology. Innovation is understood to be a function of the firm's technological and marketing resources (Nelson and Winter 1982). Prior research has concluded that marketing and technological resources are essential to pursue successful innovation (Clausen et al 2013; Acur et al. 2010; Paladino 2008). Market and sales knowledge is deemed to be essential for innovation success, leading to firm's growth. For example, Clausen et al (2013) conclude that knowledge about markets and sales is important because these resources allow a firm to exploit opportunities. Not only does a firm's knowledge about customers and their problems allow for the identification of market opportunities, but also its commercial knowledge determines the market value and opportunity for new technological change. Shane (2000) and Von Hippel (1988) also found that the lack of customer familiarity and knowledge of market leads to difficulties for firms to recognize solutions to customer needs and to formulate effective business strategies. These arguments lead us to propose:

H2a: The lack of market knowledge is negatively associated with radical innovation.

H2b: The lack of market knowledge is negatively associated with incremental innovation.

H2c: The lack of market knowledge is negatively associated with sales growth in radical innovation (H2c-a) and in incremental innovation (H2c-b).

H2d: The lack of market knowledge is negatively associated with R&D growth in radical innovation (H2d-a) and in incremental innovation (H2d-b).

H3a: The lack of sales knowledge is negatively associated with radical innovation.

H3b: The lack of sales knowledge is negatively associated with incremental innovation.

H3c: The lack of market knowledge is negatively associated with sales growth in radical innovation (H3c-a) and in incremental innovation (H3c-b).

H3d: The lack of market knowledge is negatively associated with R&D growth in radical innovation (H3d-a) and in incremental innovation (H3d-b).

The Lack of Technological Knowledge/Skills

For innovation, technological knowledge, know-how and skills are critical in the exploitation and the exploration of opportunities (March 1991). For example, McEvily and Chakravarthy (2002) have pinpointed and technological knowledge enhances a firm's ability to determine the optimal design, functionality and reliability in innovation process, and ultimately the economic impact of exploiting opportunity for competitiveness. In other words, the knowledge and skill of production plays an important role in promoting firm's innovation and long-term growth. Baldwin and Lin (2002) also conclude that technological resources facilitates innovative breakthrough and explore new opportunities. Interestingly, Mohnen and Rosa (2000) have claimed a different result by using Canadian services over the period of 1996 – 1998. They find that the most innovation-intensive firms are also those reporting more frequent obstacles to innovation. Along the same lines, Iammarino et al. (2009) also find support to a positive association between the lack of technological knowledge and innovation performance. To better understand these constraints of technological resources, we test the lack of knowledge in production and in R&D. Therefore,

H4a: The lack of production knowledge is negatively associated with radical innovation.

H4b: The lack of production knowledge is negatively associated with incremental innovation.

H4c: The lack of production knowledge is negatively associated with sales growth in radical innovation (H4c-a) and in incremental innovation (H4c-b).

H4d: The lack of production knowledge is negatively associated with R&D growth in radical innovation (H4d-a) and in incremental innovation (H4d-b).

H5a: The lack of R&D knowledge is negatively associated with radical innovation.

H5b: The lack of R&D knowledge is negatively associated with incremental innovation.

H5c: The lack of R&D knowledge is negatively associated with sales growth in radical innovation (H5c-a) and in incremental innovation (H5c-b).

H5d: The lack of R&D knowledge is negatively associated with R&D growth in radical innovation (H5d-a) and in incremental innovation (H5d-b).

The Lack of Financial Knowledge/Skills

In the innovation management literature, a disproportionate large proportion of the resources studies have focused on the effects of financial and regulation resources and constraints; specifically on firm's cash flow sensitive to afford R&D and innovation investments and the need to fulfil national and international regulations (e.g. Hall 2002; Tourigny and Le 2004; Mohnen and Röller 2005; Tiwari et al. 2007; Savignac 2008; Mancusi and Vezzulli 2010; Hottenrott and Peters 2011; Keupp and Gassmann 2014). However, like the lack of technological knowledge, the conclusion of the impact of these resources constraints on innovation is inconsistent. For example, Savignac (2008) has empirically evidenced that firms encounter financial constraints significantly lowers the likelihood of the engagement in innovative activities. This conclusion is resonated with the results found by Canepa and Stoneman (2007) and Hall (2002) who study financial constraints in small firms and in high-tech sectors. However, contradictory findings are also reported. For example, Keupp and Gassmann (2014), through a longitudinal study, have found that financial constraints do not fully hamper innovation performance. They suggest that the lack of financial resource may trigger the firm's entrepreneurial behaviour to overcome financial constraints is a major indicator for entrepreneurial. These inconsistent conclusions lead us to test:

H6a: The lack of financial knowledge is negative associated with radical innovation.
H6b: The lack of financial knowledge is negative associated with incremental innovation.
H6c: The lack of financial knowledge is negative associated with sales growth in radical innovation (H6c-a) and in incremental innovation (H6c-b).
H6d: The lack of financial knowledge is negative associated with R&D growth in radical innovation (H6d-a) and in incremental innovation (H6d-b).

Figure 1 illustrates our research framework.

RESEARCH METHOD

This analysis is based upon a unique, longitudinal panel dataset of 241 UK and German firms in six technology-based sectors over ten years. The dataset draws upon performance data as well as the results of detailed managerial surveys that were carried out in the UK and

Germany originally in 1997 and again in 2003. This, combined with information provided by interviewees about the firms' characteristics upon founding, provides a unique and rich longitudinal perspective on factors contributing to the long-run performance of these firms.

Sample selection and data collection

While the term 'high tech' is in common usage, the actual categorization of firms as 'high-tech' is not a trivial exercise. Our sample uses Butchart's (1987) definitions for high-technology manufacturing sectors in the UK, which is based on the 'ratio of R&D expenditures to sales' and the 'share of employees working in R&D.' Using this definition, Butchart identified nineteen 1987 SIC codes, which were translated into the NACE Rev. 1 code. These may loosely be defined to include firms in the electronics, software, advanced materials, telecommunications and biotechnology sectors.

This study is based on two surveys that were carried out in the UK and Germany originally in 1997 and again in 2003. Using these databases, all firms with at least three employees in 1997 that were operating in one or more high-tech sectors (using the definition above) and having been founded as legally independent companies between 1987 and 1996 were selected; the mean year of founding was 1991. Subsidiaries, de-mergers or firms that were founded as a management buy-out (MBO) or buy-in (MBI) were excluded from the analysis.

These firms were first contacted in winter 1997/1998 via a written questionnaire after an initial series of pilot interviews. Ultimately 362 completed questionnaires were returned. This research was then followed up with a new survey in which all previously responding firms were to be contacted a second time in 2003. At this date the average respondent firms were approximately 12 years old. The second survey was conducted in 2003 via computer-aided telephone interviews (CATI).

Variables

For our innovation variables we use questions asked in the questionnaire about the nature of the innovative activities of the firms in question. Specifically for firms with radical innovations we counted these as firms that were generating innovations internally for which the product was novel in the marketplace. We counted as incremental the innovation which involved the combination of existing technologies. Firms primarily using innovations developed outside the firm were not counted either way. Our dependent variables were initially the radical and incremental variables, and then also measures for innovation growth and sales growth. For the prior measure we used growth in R&D spending while for the latter we used turnover. For the sales figure we used log difference, taking the form:

$$growth\_sales = \ln(sales\_tn+1) - \ln(sales\_tn)$$

The key independent variables are questions that ask the respondents about the lack of access to specific resources in certain areas, namely management, finance, R&D, production and sales. These are all coded as binary variables. For our controls we use a number of measures to control for potential explanatory factors contributing to firm performance. We control for age and size (i.e. employment), including the variables and their squared terms to capture potential quadratic effects on performance. We control for the frequency of innovation. We also control for exporting behaviour, also using a binary variable. We also use measures to proxy general human capital levels within the firm, specifically using measures of the percentage of employees who are graduates with technical and the proportion who are graduates. Finally, we control for industry (using the coding identified above) and region.

Method

Our approach to the problem involves initial use of panel logit models to predict the likelihood of a firm engaging in incremental or radical innovation. Our model is specified in a manner that we consider the lagged effect of the resource constraints in t0 on propensity for innovation in period t1. Our other controls listed above all are used for period t1 . Given challenges in interpreting logit models we present the results in the form of marginal effects. Following from this analysis we then use panel OLS models to explore the impact of these constraints on subsequent innovation and growth performance. As discussed above, we then run an alternate model considering the interaction terms of the constraints on radical and incremental innovation.

RESULTS

The results of our initial analysis are provided in Tables 1-5. Tables 1 and 2 provide descriptive analysis of our data, with general descriptions of the data and a correlation matrix, respectively. These descriptives show the general structure of the data. The mean firm size is 17, with the largest firm having 314 employees, meaning that these firms are all comfortably classified as SMEs.

Our multinomial analysis is presented beginning in Table 3. We present in Equation 1 a baseline model predicting likelihood of radical innovation with our main components, before introducing the constraint measures in Equation 2. The constraint measures are lagged while the other measures are not. From here it can be seen that there is no significant relationship between constraints and radical innovation. In Equations 3 and 4 we can see similar models for incremental innovations, but again we have the same findings. From these results, it appears that there is no direct predictive link between constraints and innovation.

However when we extend our findings to growth measures, we find a different story. The results for the analysis of sales growth is presented in Table 4. Equation 5 shows another baseline model, before Equation 6 includes the lagged constraint variables. We see that in this model firms with constraints around R&D or management are less likely to show sales growth. In Equation 7 we then introduce the interaction terms for radical innovations, which shows that firms engaging in radical innovations but with managerial resource shortfalls were significantly less likely to grow. However in this model we find that firms that are financially constrained are more likely to grow, which is surprising. In Equation 8 we find that financially constrained incremental innovators are much more likely to grow.

Finally we consider the contribution of these factors to R&D growth, as presented in Table 5. Equation 9 shows the baseline of the model. Table 10 includes the constraint data only as well as the baseline, and finds a strong negative effect for firms with production shortfalls. Table 11 then includes radical innovation findings. Unsurprisingly it finds that firms that are constrained with regard to innovation have lower R&D performance, though this only comes out when the controls for radical innovation are introduced. We find a positive association between financial constraints and R&D in this model as well. Table 12 then controls for incremental innovation, and finds positive results for those firms with marketing shortfalls, but negative results for firms with production shortfalls.

DISCUSSION AND CONCLUSION

Combining the theories of human capital, entrepreneurship and resource-based view, this study examined how a hi-tech firm's knowledge shortfalls influence its performance in innovation and growth. Our data have indicated that the shortfalls of knowledge in management (H1a & H1b), market (H2a & H2b), sales (H3a & H3b), production (H4a & H4b), R&D (H5a & H5b) and finance (H6a & H6b) are not significantly associated with radical or incremental innovation. All the six sets of Ha and Hb are rejected. In radical innovation, our analysis has shown the following significant results: (1) the lack of management knowledge is significantly associated with sales growth (H1c-a is negatively supported); (2) the lack of R&D knowledge is associated with R&D growth (H5d-a is negatively supported); and (3) the lack of financial knowledge is negatively associated with R&D growth (H6d-a is supported). In incremental innovation, results have suggested that (1) the lack of financial knowledge is negatively associated with sales growth (H6c-b is supported); (2) the lack of market knowledge is negatively associated with R&D growth (H2d-b is supported); and (3) the lack of production knowledge is associated with R&D growth (H4d-b is negatively supported).

Does the lack of knowledge hamper or trigger innovation?

The answer is rather mixed. While our study indicates that the lack of knowledge may not hamper innovation development for both incremental and radical, it suggests that the lack of knowledge does matter when considering sales growth and R&D growth.

For radical innovation, our study suggests that the lack of management knowledge may trigger sales growth. This result is supported by Keupp and Gassmann (2013) who have empirically evidenced and suggested that firms should promote entrepreneurial spirit to encourage radical innovativeness. In this sense, the lack of management knowledge may path a leeway for employees to take a more novel approach for the opportunities for sales growth. Un-surprized, the lack of R&D knowledge triggers R&D growth of firms. This may be explained in two ways. First, the lack of R&D knowledge leads firm to increase R&D investment. Furthermore, the nature of radical innovation may also lead the innovative firms to discard prior R&D knowledge in order to build up new R&D knowledge. This is supported by Liu and Hart (2011) who have evidenced that prior experience does not impact on radical innovation. Therefore, the lack of R&D knowledge may promote R&D growth. Finally, our study echoes the extant literature that the lack of financial knowledge hampers the R&D growth.

For incremental innovation, our study once again stresses the significant impact of the lack of financial knowledge on innovation and suggests that the shortfall of financial knowledge hampers sales growth. It further suggests that the lack of market knowledge hampers R&D growth. This result enhances Schumpter's (1934) contention that innovation is the market introduction and commercialization of new technology. This result also suggests that market knowledge is critical for firms in deciding their R&D investment. Finally, our study suggests that the lack of production knowledge triggers R&D growth. Managers tend to increase R&D investment when they need production knowledge.

In conclude, through a ten-year longitudinal study, our study contributes to the existing literature by advancing the understanding of the association between resources constraints and innovation. Building on the theories of human capital, entrepreneurship and RBV, we shed light about the impact of knowledge shortfalls on both radical and incremental innovation. Finally, our study helps to explain the disputes of whether resource constraints hamper or trigger innovation. The study also has implications for executives and managers. It demonstrates that managers can harness the entrepreneurship practices by minimizing their interference for radical innovativeness. Managers and innovators hare encouraged to update their market knowledge that serves an important indicator for R&D investment. Furthermore, as suggested by many researchers, financial knowledge is always important in operating and managing innovation for both sales and R&D growth. Indeed, ‘innovative firms face problems and more innovative firms have more problems’ (Galia and Legros 2004, p. 1189). We hope our paper inspires researchers to conduct further research in the future.

Finally, our study has some limitations the reader should be aware of. First, our samples ae collected from two countries – the UK and Germany. While we controlled for national differences we did not compare the differences between these two countries. This leads to a topic for further research. Moreover, we are aware that our data is not recent, although we are also confident that similar data collected now would be yield similar results. We are in the process of updating our survey with more recent findings and will then be able to verify our findings.

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Figure 1: Research Framework

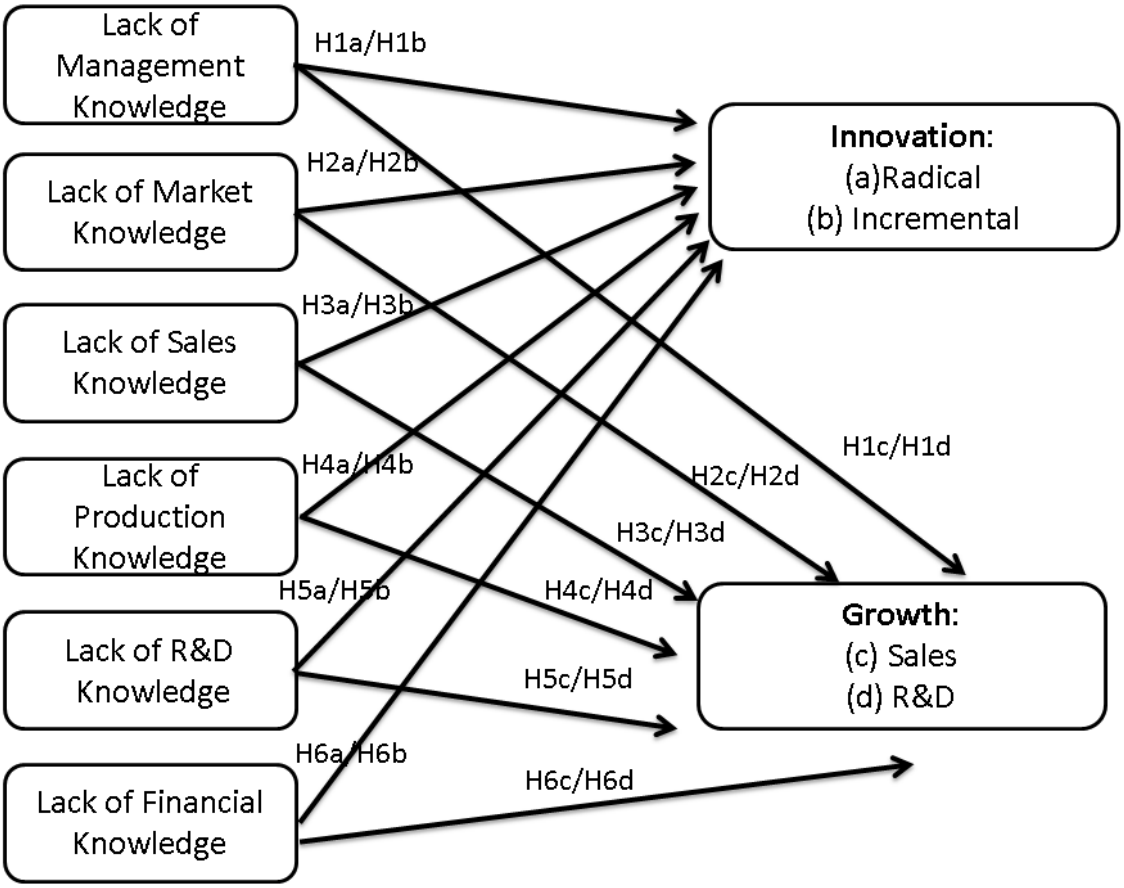

Table 1: Descriptive Statistics

Variable	**Definition**	**Obs**	**Mean**	**Std. Dev.**
radical	Radical innovation	462	0.3593074	0.4803175
incremental	Incremental innovation	462	0.2662338	0.4424671
constraint_mark	Constrained by marketing	482	0.2759336	0.4474479
constraint_fin	Constrained by finance	482	0.159751	0.3667557
constraint_man	Constrained by management	482	0.1286307	0.3351386
constrain_prod	Constrained by production	482	0.1556017	0.3628539
constrain_rd	Constrained by R&D	482	0.159751	0.3667557
constraint_sale	Constrained by sales	482	0.2780083	0.448483
radical_mark	Radical*Constrained by marketing	227	0.0704846	0.2565276
radical_fin	Radical*Constrained by finance	227	0.0176211	0.1318607
radical_mana	Radical*Constrained by management	227	0.030837	0.173258
radical_sale	Radical*Constrained by production	227	0.0660793	0.2489697
radical_prod	Radical*Constrained by R&D	227	0.0572687	0.2328689
radical_rd	Radical*Constrained by sales	227	0.0528634	0.2242553
inc_mark	Incremental*Constrained by marketing	227	0.0528634	0.2242553
inc_fin	Incremental*Constrained by finance	227	0.0264317	0.1607699
inc_mana	Incremental*Constrained by management	227	0.030837	0.173258
inc_sale	Incremental*Constrained by production	227	0.0660793	0.2489697
inc_prod	Incremental*Constrained by R&D	227	0.0220264	0.1470938
inc_rd	Incremental*Constrained by sales	227	0.0528634	0.2242553
founder	Size of founding team	723	2.228216	1.280227
empuni_p	Percentage grad employees	208	36.38676	29.26781
intsales	Exporting	712	0.5758427	0.4945618
f_year	Founding year	723	1989.946	4.410843
emp	Employment	719	17.18359	25.95539
emp2	Employment squared	719	968.0209	5783.728

Table 2 Correlation Table

	Radical	Incremental	constraint_mark	constraint_fin	constraint_man	constrain_prod	constrain_rd
Radical	1.000						
Incremental	-0.298	1.000					
constraint_mark	-0.037	0.035	1.000				
constraint_fin	-0.052	0.048	0.225	1.000			
constraint_man	0.028	0.011	0.234	0.272	1.000		
constrain_prod	0.005	-0.009	0.158	0.125	0.331	1.000	
constrain_rd	-0.052	-0.019	0.212	0.073	0.222	0.328	1.000
constraint_sale	0.017	0.040	0.601	0.260	0.204	0.270	0.147
founder	0.017	-0.022	0.050	0.064	0.067	0.049	-0.016
empuni_p	0.105	-0.107	-0.029	-0.046	0.023	0.067	0.081
intsales	0.123	0.049	-0.118	0.054	0.011	-0.004	-0.014
f_year	-0.067	0.052	0.027	0.059	0.009	-0.117	-0.097
emp	0.056	-0.020	-0.093	0.022	0.040	0.027	0.046
emp2	0.070	-0.044	-0.056	-0.009	0.005	0.000	-0.003

	constraint_sale	founder	empuni_p	intsales	f_year	emp	emp2
L.constrai~e	1.000						
founder	0.078	1.000					
empuni_p	-0.039	-0.039	1.000				
intsales	-0.053	0.015	0.053	1.000			
f_year	0.031	0.060	0.036	0.000	1.000		
emp	-0.049	0.133	-0.039	0.250	-0.146	1.000	
emp2	-0.026	0.071	0.069	0.103	-0.075	0.812	1.000

Table 3 Logit Regression for Radical and incremental

VARIABLES	(1) Radical	(2) Radical	(3) Incremental	(4) Incremental
L.constraint_mark		-0.441		0.0277
		(0.499)		(0.631)
L.constraint_fin		-0.0830		-0.607
		(0.567)		(0.726)
L.constraint_mana		0.124		-0.299
		(0.563)		(0.727)
L.constraint_prod		-0.713		-0.183
		(0.522)		(0.642)
L.constraint_rd		0.507		-0.112
		(0.505)		(0.641)
L.constraint_sale		0.433		-0.119
		(0.491)		(0.592)
founder	0.0967	0.0995	-0.0943	-0.109
	(0.118)	(0.120)	(0.149)	(0.158)
empuni_p	0.00812	0.00841	-0.00721	-0.00749
	(0.00566)	(0.00577)	(0.00726)	(0.00735)
intsales	0.610	0.609	0.313	0.353
	(0.399)	(0.406)	(0.498)	(0.505)
f_year	-0.0592	-0.0632*	0.0929	0.0979*
	(0.0363)	(0.0374)	(0.0574)	(0.0585)
emp	-0.0124	-0.0143	0.0107	0.0135
	(0.0157)	(0.0165)	(0.0196)	(0.0203)
emp2	0.000102	0.000115	-7.58e-05	-8.70e-05
	(0.000125)	(0.000132)	(0.000165)	(0.000168)
Industry controls	YES	YES	YES	YES
Constant	117.2	125.5*	-186.2	-196.1*
	(72.20)	(74.54)	(114.3)	(116.6)
Observations	199	199	199	199
R-squared				

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: OLS models for sales growth

	(5)	(6)	(7)	(8)
VARIABLES	Sales growth	Sales growth	Sales growth	Sales growth
L.constraint_mark		-0.0178	0.0313	0.0896
		(0.116)	(0.149)	(0.160)
L.constraint_fin		0.159	0.348*	-0.0265
		(0.170)	(0.201)	(0.202)
L.constraint_mana		-0.251*	0.0215	-0.341
		(0.148)	(0.205)	(0.207)
L.constraint_prod		-0.0457	-0.470	0.0651
		(0.225)	(0.295)	(0.294)
L.constraint_rd		-0.284*	-0.177	-0.251
		(0.152)	(0.186)	(0.190)
L.constraint_sale		-0.0629	-0.213	-0.235
		(0.128)	(0.158)	(0.183)
L.radical_emp			-0.205	
			(0.285)	
L.radical_fin			0.0317	
			(0.478)	
L.radical_mana			-0.814**	
			(0.377)	
L.radical_sale			0.463	
			(0.328)	
L.radical_prod			0.672	
			(0.457)	
L.radical_rd			0.0820	
			(0.364)	
L.inc_emp				-0.156
				(0.235)
L.inc_fin				0.647**
				(0.305)
L.inc_mana				0.203
				(0.291)
L.inc_sale				0.422
				(0.263)
L.inc_prod				-0.284
				(0.423)
L.inc_rd				0.0417
				(0.269)
tecint	0.0624	0.0741	0.0675	
	(0.120)	(0.127)	(0.116)	
teccomb	0.117	0.107		0.0229
	(0.150)	(0.148)		(0.128)
founder	-0.00298	-0.0117	-0.00603	0.0146
	(0.0363)	(0.0354)	(0.0366)	(0.0348)
empuni_p	0.000617	0.00104	0.00153	0.00120
	(0.00254)	(0.00253)	(0.00264)	(0.00231)
intsales	0.295**	0.251*	0.109	0.218
	(0.146)	(0.140)	(0.150)	(0.145)
f_year	0.0291*	0.0289*	0.0281*	0.0255
	(0.0165)	(0.0163)	(0.0165)	(0.0173)
emp	0.00659**	0.00808**	0.00974***	0.00784**
	(0.00329)	(0.00328)	(0.00349)	(0.00365)
emp2	-1.06e-05	-1.51e-05*	-1.91e-05**	-1.41e-05
	(8.87e-06)	(8.95e-06)	(9.49e-06)	(9.86e-06)
Industry controls	YES	YES	YES	YES
Constant	-56.60*	-56.25*	-53.48	-49.08
	(32.67)	(32.31)	(32.75)	(34.39)
Observations	180	180	169	169
R-squared	0.123	0.165	0.220	0.212

Standard errors in parentheses ***P<0.01 **p<0.05 *p<0.1

Table 5 – OLS Regression for R&D

VARIABLES	(9) R&D	(10) R&D	(11) R&D	(12) R&D
L.constraint_mark		9.175	6.384	13.64*
		(5.560)	(3.931)	(7.938)
L.constraint_fin		4.813	9.978*	0.900
		(5.114)	(5.583)	(9.127)
L.constraint_mana		-5.257	-4.590	-7.044
		(3.400)	(3.074)	(5.676)
L.constraint_prod		-8.443***	-3.510	-10.07**
		(2.616)	(3.405)	(4.019)
L.constraint_rd		-4.816	-8.835***	-5.576
		(3.468)	(3.090)	(5.089)
L.constraint_sale		3.325	-2.269	4.964
		(4.246)	(3.286)	(7.400)
L.radical_emp			10.48	
			(15.02)	
L.radical_fin			-11.66	
			(9.258)	
L.radical_mana			1.033	
			(10.90)	
L.radical_sale			15.13	
			(14.78)	
L.radical_prod			-12.65	
			(8.165)	
L.radical_rd			0.113	
			(13.73)	
L.inc_emp				-13.08
				(9.241)
L.inc_fin				6.986
				(9.431)
L.inc_mana				5.964
				(7.087)
L.inc_sale				-2.759
				(9.044)
L.inc_prod				4.316
				(5.828)
L.inc_rd				0.139
				(5.774)
tecint	9.575***	9.627***	9.970***	
	(3.199)	(3.119)	(3.522)	
teccomb	1.242	1.146		-6.748*
	(2.701)	(2.667)		(3.486)
founder	-0.644	-0.788	-0.829	-0.274
	(0.901)	(0.922)	(0.984)	(1.012)
empuni_p	0.229***	0.246***	0.240***	0.248***
	(0.0863)	(0.0864)	(0.0871)	(0.0945)
intsales	8.474***	8.863***	6.838**	10.64***
	(2.273)	(2.358)	(2.818)	(3.215)
f_year	0.195	0.136	0.0591	0.0872
	(0.242)	(0.244)	(0.222)	(0.271)
emp	-0.0530	-0.0161	-0.0140	-0.00246
	(0.0581)	(0.0594)	(0.0721)	(0.0703)
emp2	0.000259*	0.000173	0.000163	0.000152
	(0.000152)	(0.000168)	(0.000205)	(0.000198)
Industry controls	YES	YES	YES	YES
Constant	-393.3	-280.0	-128.6	-179.8
	(481.5)	(488.4)	(442.2)	(541.8)
Observations	185	185	173	173
R-squared	0.209	0.263	0.295	0.241

Standard errors in parentheses ***P<0.01 **P<0.05 *P<0.1